Phase II
Flight Safety Data Package
for the
Human Research Facility

July, 1997
(Original Release)

**National Aeronautics and
Space Administration**

**Lyndon B Johnson Space Center
Houston, Texas 77058**

LS-71027-3

PREFACE

This addition to the Human Research Facility (HRF) Phase II Flight Safety Data Package represents Chapter 8 of LS-71027-3. This chapter covers the Refrigerated Centrifuge, which replaces the ambient centrifuge that was originally planned as part of the HRF hardware complement. This design is being presented to the Payload Safety Review Panel at a Phase II/Critical Design Review level.

All verifications related to this hardware item remain open.

TABLE OF CONTENTS

8.0	<u>REFRIGERATED CENTRIFUGE</u>	8-1
8.1	HARDWARE DESIGN	8-1
8.1.1	<u>Refrigeration System</u>	8-1
8.1.2	<u>Rotor Assembly</u>	8-4
8.2	OPERATIONS	8-5
8.2.1	<u>Launch/Ascent and Transport to Station</u>	8-5
8.2.2	<u>On-Orbit Scenario</u>	8-5
8.2.3	<u>Rapid Safing</u>	8-6
8.2.4	<u>Fire Protection</u>	8-6
8.2.5	<u>Maintenance and Calibration</u>	8-6
8.2.6	<u>Aging and Disposal</u>	8-7
8.3	REFRIGERATED CENTRIFUGE INTERFACE REQUIREMENTS	8-7
8.3.1	<u>Stowage</u>	8-7
8.3.2	<u>Crew</u>	8-7
8.3.3	<u>Power</u>	8-7
8.3.4	<u>Data</u>	8-7
8.4	REFRIGERATED CENTRIFUGE SAFETY ASSESSMENT	8-8
8.4.1	<u>Human Factors</u>	8-8
8.4.2	<u>Materials</u>	8-8
8.4.3	<u>Electrical</u>	8-9
8.4.4	<u>Rapid Safing</u>	8-9
8.4.5	<u>Structures</u>	8-9

APPENDICES

8A	Standard Hazards for the Refrigerated Centrifuge	8A-1
8B	Unique Hazards for the Refrigerated Centrifuge	8B-1

ACRONYMS AND ABBREVIATIONS - Updated

AC	Alternating Current
A/D	Analog to Digital
ADAS	Ambulatory Data Acquisition System
AM	Analyzer Module
BCK	Blood Collection Kit
BDC	Baseline Data Collection
BDL	Barcode Data Logger
BRP	Biological Research Project
CBPD	Continuous Blood Pressure Device
CDR	Critical Design Review
CFR	Code of Federal Regulations
CG	Center of Gravity
CHeCS	Crew Health Care System
COTS	Commercial-Off-The-Shelf
CP	Control Panel
CPU	Central Processing Unit
CV/CP	Cardiovascular/Cardiopulmonary
DARA	Deutshe Agentur fur Raumfahrt Angelegenheiten
DAS	Data Acquisition System
DC	Direct Current
DOF	Degrees of Freedom
DSO	Detailed Supplemental Objective
DTO	Detail Test Objective
ECG	Electrocardiograph
ECLSS	Environmental Control and Life Support System
EEG	Electroencephalogram
EMG	Electromyograph
EMI	Electromagnetic Interference
EOG	Electrooculograph

ESA	European Space Agency
EUE	Experiment Unique Equipment
EVA	Extravehicular Activity
EXPRESS	EXpedite the PRocessing of Experiments to the Space Station
FC	Frequency Converter

FCA	Flight Calibration Assembly
FCSD	Flight Crew Systems Division
FGI	Foot Ground Interface
FSD	Flat Screen Display
g	gravitational force
GASMAP	Gas Analyzer System for Metabolic Analysis of Physiology
GDS	Gas Delivery System
GFE	Government Furnished Equipment
gm	gram
H	Henry
HGD	Hand Grip Dynamometer
HR	Hazard Report
HRF	Human Research Facility
Hz	Hertz
IC	Integrated Circuit
IDD	Interface Definition Document
IFM	In-Flight Maintenance
I/O	Input/Output
IRB	Institutional Review Board
IS	Interface Shell
ISPR	International Standard Payload Rack
ISS	International Space Station
IUCA	Inflight Urine Collection Absorber
IVA	Intravehicular Activity

JSC	Johnson Space Center
LAN	Local Area Network
LBNP	Lower Body Negative Pressure
LCD	Liquid Crystal Display
LEA	Lower Extremity Assembly
LED	Light Emitting Diode
LMS	Life and Microgravity Sciences
LSE	Laboratory Support Equipment
MBPD	Manual Blood Pressure Device
mmHg	millimeters of Mercury

ACRONYMS AND ABBREVIATIONS (Continued)

MMS	Marquette Medical Systems
MPLM	Mini Pressurized Logistics Module
MSFC	Marshall Space Flight Center
MUA	Materials Usage Agreement
N/A	Not Applicable
NiMH	Nickel Metal Hydride
Ni-Cd	Nickel Cadmium
NTC	Negative Temperature Coefficient
PC	Portable Computer
PCB	Printed Circuit Board
PCMCIA	Personal Computer Memory Card Industry Association
PCS	Portable Computer System
PDR	Preliminary Design Review
PED	Payload Element Developer
PEMS	Percutaneous Electrical Muscle Stimulator
PSC	Physiological Signal Conditioners
PSRP	Payload Safety Review Panel
PU	Panel Unit
PVC	Polyvinyl Chloride

QA	Quality Assurance
RAMS	Random Access Mass Spectrometer
RC	Refrigerated Centrifuge
RDAS	Rack mounted Data Acquisition System
R/F	Refrigerator/Freezer
RIC	Rack Interface Controller
RID	Review Item Disposition
RIP	Respiratory Impedance Plethysmograph
ROMS	Range of Monitor Suit
RPCM	Remote Power Control Module
RPM	Revolutions per Minute
RSP	Resupply Stowage Platform
RVC	Rack Volume Closeouts
SCK	Saliva Collection Kit
SIM	Skin Impedance Meter

ACRONYMS AND ABBREVIATIONS (Continued)

SIR	Standard Interface Rack
SLAMMD	Space Linear Acceleration Mass Measurement Device
SMD	Strength Measurement Device
SPR	Skin Potential Response
TBD	To Be Determined
TIM	Technical Interchange Meeting
TPS	Test Preparation Sheet
UCD	Urine Collection Device
UCK	Urine Collection Kit
UEA	Upper Extremity Assembly
UF-1	Utilization Flight One
US LAB	United States Laboratory
UOP	Utility Outlet Panel
VTR	Video Tape Recorder

WCS	Waste Collection System
WPA	Waist Pack Assembly
WS	Workstation

8.0 REFRIGERATED CENTRIFUGE

A centrifuge is a mechanical device used to separate substances of different densities. Centrifuges may be used to quickly separate substances that would normally separate slowly under the influence of gravity. The refrigerated centrifuge is intended to provide a system of separation of biological samples based on differing sample densities. The centrifuge will be capable of separating blood into its components, and also capable of separating saliva from saturated dental cotton rolls. The centrifuge will provide refrigeration down to +4^{o}C, and below, to all samples. The refrigerated centrifuge consists of three main components: the refrigeration system, the rotor assembly and an integral stowage drawer.

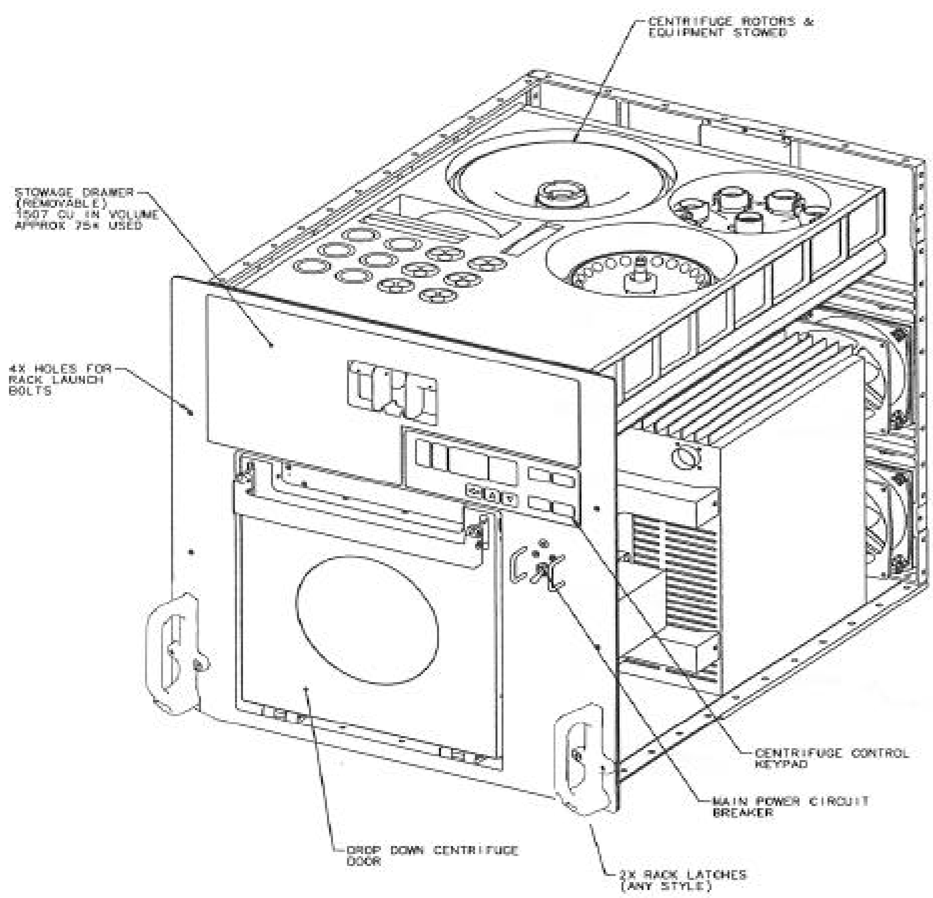


Figure 8.0-1

8.1 HARDWARE DESIGN

8.1.1 Refrigeration System

The refrigeration method utilized by the centrifuge is vapor compression cycle. Vapor compression systems consist of four components: a compressor, a condenser, an evaporator, and an expansion device (See Figure 8.1.1-1). The compressor takes low pressure, low temperature refrigerant gas and compresses it to high pressure, high temperature gas. The compressor accomplishes this in a manner similar to that of an automobile engine. Reciprocating pistons intake vapor at low pressure, and compress the vapor before sending it to the discharge line. The cool, low pressure gas entering the compressor is referred to as suction gas. The high pressure, high temperature gas exiting the compressor is called discharge gas. The commercial compressor relies on oil sumping at the bottom of the compressor to lubricate the gears and therefore is gravity dependent.

From the compressor, the hot, high pressure gas travels through the discharge line into the condenser. The condenser is the part of the system where the heat is rejected by, as the name implies, condensation. An everyday example of condensation is a container of cold water left outside on a hot summer afternoon. Since the surface of the container is cooler than the air that surrounds it, water begins to leave the air, and form drops on the container. As the water condenses from the air onto the surface of the container, it loses energy, and therefore cools. In the vapor compression system, as the hot gas travels through the condenser, it is cooled by air passing over it. As the hot gas refrigerant cools, drops of liquid refrigerant form within the coil. Eventually, when the gas reaches the end of the condenser, it has condensed completely, that is, only liquid refrigerant is present. Just like the water condensing onto the surface of the container of cool water, the refrigerant has lost some of its energy and cooled. In order for the condenser to function correctly, the fluid passing through

the fins of the condenser (usually air) must be cooler than the working fluid of the system (freon).

The purpose of the expansion device in a vapor-compression refrigeration cycle is to control the flow of refrigerant to the evaporator. As the refrigerant leaves the condenser, it has cooled, and condensed to liquid, but is still under high pressure. In order for the liquid to absorb the necessary heat in the evaporator, its pressure must be reduced, which is accomplished within the expansion device. The refrigerated centrifuge uses a capillary tube to accomplish this. Capillary tubes are lengths of tubing with a small inside diameter, which regulate fluid control through careful control of length and diameter. When compared with other expansion devices, the use of capillary tubes allow for less refrigerant in the system, as well as the elimination of the need for additional components such as sight glasses or receivers.

The evaporator is the component of the cycle that actually absorbs the heat from the conditioned space. The evaporator is similar in construction to the condenser, but its function is opposite. Thinking back to the container of water that was left outside on a hot summer afternoon, imagine that the container sits in the sun, and has warmed. As the water continues to warm, it evaporates, leaves the container and becomes vapor. This is the same process that happens to the refrigerant inside the evaporator. As the fluid leaves the expansion device, it is a cool liquid. As it passes through the evaporator, it picks up heat from the room, and evaporates into a gaseous form. This evaporation is what enables the refrigerant to absorb the heat energy from the room.

As the refrigerant leaves the evaporator, it is returned to the cooled, low pressure state, and is sent back to the compressor to begin the cycle again. Under normal circumstances the refrigerant will not wear out, it will be reused again and again, changing its physical form, but not its chemical composition. The refrigerated centrifuge uses R404a as its working fluid. R404a is environmentally friendly and has been given a toxicity level of 0 (reference memo #458). This refrigerant will only degrade under extremely high temperatures (>800 ºC) and according to the JSC toxicologist the degradation products from this refrigerant would be less hazardous than those of other items such as Teflon wire. An evaluation was performed by ECLSS on this refrigerant and it was found to be acceptable with no deleterious interactions with LiOH. See unique hazard report RC-4 and associated attachments.

The HRF Refrigerated Centrifuge (RC) is a Commercial Off the Shelf (COTS) unit that will be modified to meet flight requirements. The unit has a brushless dc motor and the speed is adjustable. Modifications made to the unit are:

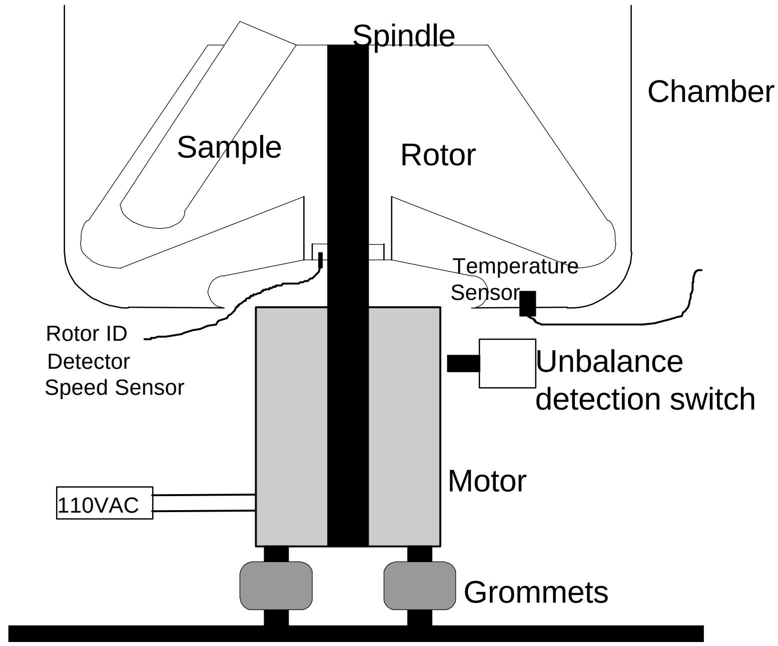
1. Modify compressor to remove oil and replace oil-lubricated parts with self-lubricating parts.
2. Conformal coat the Printed Circuit Boards
3. Repackage internal components
4. Add labels
5. Add vibration isolation to reduce disturbances to the rack
6. Add sensors to monitor temperature, pressure and current parameters.
7. Health and status data will be monitored and sent via Ethernet to the Rack Interface Controller (RIC) and then to the ground. This data will include high and low pressure readings and compressor current.

Additional features of the centrifuge are:

1. It is capable of running from 1 to 30 minutes, selectable in one minute increments, with a hold feature to allow for indefinite run times.
2. It provides selectable speed over the range of 1,000-14,000 RPM, selectable in increments of 100 RPM.
3. It accommodates sample sizes from 0.5 to 50 ml and accommodates 6, 50 ml. vials simultaneously.

4. It provides programmable centrifugation protocols that may be overridden if necessary.
5. It provides an LED to signal when the centrifuge is spinning and one to indicate when the centrifuge protocol has ended.
6. It provides an LED to indicate when the door latch is fully engaged.
7. It provides emergency stop capability, via the front panel keypad, stopping in <30 seconds.
8. It provides the capability to detect unbalanced conditions during centrifugation and automatically shut down the centrifuge. A micro-switch is located below the rotor chamber and is triggered if the rotor nears the wall of the chamber. Unbalanced conditions are most likely to occur during start-up – before the rotor reaches full operating speeds.
9. It provides refrigeration of the rotor chamber from ambient to $+4^oC$, selectable in increments of 2^oC. Note: the commercial unit is capable of reaching -20^oC, but no experiment protocols are expected to go below $+4^oC$. In the unlikely event a temperature below -18^oC was requested, that experiment would be required to provide thermal protection for the crew as necessary.
10. Rotor acceleration and deceleration can be manually controlled.
11. The temperature of the rotor chamber is displayed on front panel LCD continuously while the rotor is being spun.
12. The rotor speed is displayed on front panel LCD continuously while in use.
13. The rotor being used is automatically sensed to ensure proper speeds are used.

The sensors mentioned in items 8, 11, 12 and 13 are depicted in figure 8.1.1-2.



CENTRIFUGATION - FUNCTIONAL BLOCK DIAGRAM

Figure 8.1.1-2

8.1.2 Rotor Assembly

Currently, three rotors are being provided as part of the refrigerated centrifuge system. Each rotor is designed to hold different sized sample vials. Adapters are also available with each rotor. Adapters are hollow cylindrical tubes used to change the diameter of the rotor chambers in order to house smaller vials. The sample vials are experiment unique and will not be provided as part of the refrigerated centrifuge hardware. The rotors and adapters will be stowed in the internal stowage drawer within the overall centrifuge drawer. The table below is a description of each rotor and specific adapters.

Rotor Capacity	***7-50 ml***	***2-10 ml***	***.4-2.2ml***
Adapters	12 and 7 ml	5 ml	1.5 and .5 ml
Max speed	6000 RPM	5000 RPM	14,000 RPM

The rotor is restrained onto the spindle through the use of a taper-fit attachment and an Allen bolt.

The actual speed of the rotor is monitored and controlled via the Control Panel (CP) and Frequency Controller (FC). The CP evaluates the speed sensor once the rotor begins rotating. The speed sensor, attached to the motor, receives the following from the transmitter attached to the rotor: rotor code information and speed data. The CP compares the set RPM and starting and breaking levels with those allowed for that rotor by looking up the limits for that rotor ID in a look up table. If the requested speed is above the rated speed for that rotor, an error is displayed and the CP issues a BREAK, STOP command to the Frequency Converter (FC). The RPM value is changed to the max RPM allowed for that rotor. The user can then resume operation. If the requested speed is below the rated maximum speed, operation continues nominally. The FC continues to ramp-up the rotor to the requested RPM by increasing the driving frequency. The FC is also programmed that no value of speed in excess of the maximum permitted rotor speed can be selected. Once the set RPM is reached, the CP monitors the tachometer speed and compares it to the requested speed. If the CP were to fail, sending no data to the FC, the FC would brake and stop the rotor motor after 30 seconds.

8.1.3 Stowage Drawer

A stowage drawer is located in the upper 4PU portion of the overall Refrigerated Centrifuge drawer. The stowage drawer will contain the centrifuge rotors, adapters, and the spanner release tool required for rotor removal/replacement as well as the emergency release for opening the centrifuge drawer in a loss of power condition. A small cutout was required in the lower right-hand portion of the drawer to allow the LCD display to be oriented horizontally. Otherwise, the drawer is similar in design to the standard ISIS stowage drawers. The drawer is prevented from inadvertently being removed completely from the centrifuge by the same hook/tab devices used on other stowage drawers. To reduce the likelihood of debris entering the centrifuge area of the drawer, the drawer will not be removed during on-orbit activities. All stowed items are easily accessible without removing the stowage drawer.

8.2 OPERATIONS

8.2.1 Launch/Ascent and Transport to Station

The refrigerated centrifuge will be launched in a 12 PU drawer within the HRF rack 2**.** The rack, and centrifuge, will only be powered after integration into its station location.

8.2.2 On Orbit Scenario

The refrigerated centrifuge will be used to separate biological samples such as blood and saliva. The front panel of the 12PU drawer will open to expose the centrifuge rotor. The crewmember will select a rotor as identified in the experiment procedures. The rotor is removed and replaced with the use of the spanner release tool, which is provided as part of the centrifuge system. The Station-provided tool kit also includes an appropriate Allen wrench. The samples will be loaded and the door will be closed. The controls will be set for the appropriate time, temperature, rotor speed and ramp up and down speeds. At the end of the centrifugation, the samples will be removed and placed elsewhere according to the specific experiment protocol. The door design includes a mechanical latch, which is activated any time the rotor is spinning. See figure 8.2.2-1. The over-center hook is engaged when the door handle is closed. Once the handled is closed completely, a switch is engaged signaling when centrifugation can begin. A tab is also inserted in a slot of the hook closure to keep it closed during centrifugation. An LED indicates when this tab is in place. The solenoid that controls the tab is engaged (tab retracted) whenever centrifugation is not in progress, thus allowing the door to be opened.

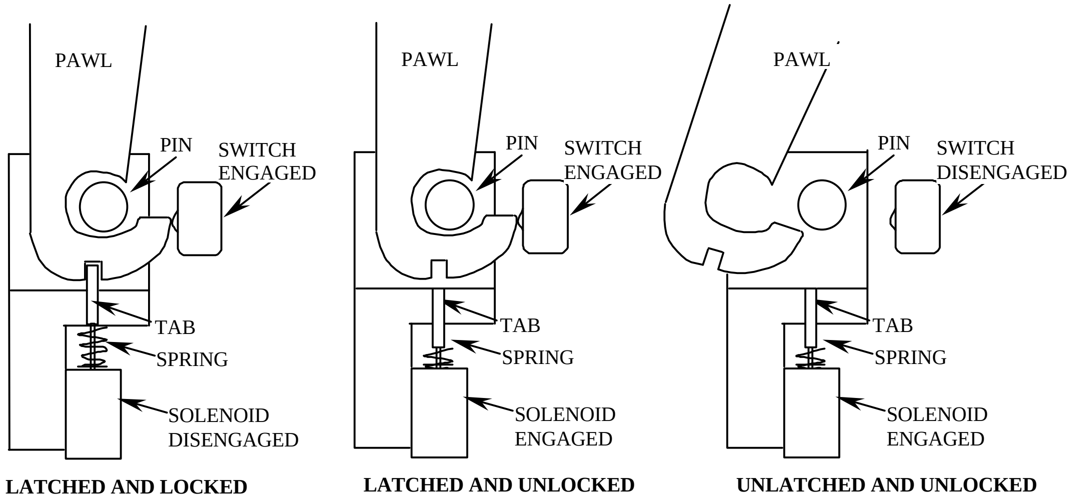


Figure 8.2.2-1

An additional latch has been added to the commercial design and is shown on figure 8.0-1. This latch will automatically be engaged when the door is closed, but must be manually removed prior to opening the door. This secondary latch prevents an inadvertent kick to the door handle from opening the door. The latch must be pushed down and the handle pulled up to open the door. An o-ring on the bottom of the rotor and a seal between the rotor and the door provide a single level of containment for biological samples only during centrifugation. Should the specific experiment require a higher level of containment, this must be provided by the experiment (per IDD LS-71078-2). The design includes a Lexan window so that sample integrity can be checked prior to opening the door.

8.2.3 Rapid Safing

No special procedures are necessary for the centrifuge in the event of a rapid safing situation.

8.2.4 Fire Protection

Fire prevention is handled in the design process. The centrifuge is made with approved materials and with proper wire sizing and circuit protection. Elimination of fire sources through conformal coating and electronic parts derating was implemented in the design. Proper grounding is also implemented.

The rack handles fire detection and suppression. The centrifuge has forced airflow to the rear of the drawer and into the rack where a smoke detector is present. The rack includes a Portable Fire Extinguisher port which would be used in the event of a fire anywhere within the rack.

8.2.5 Maintenance and calibration

The centrifuge motor and refrigeration system will be mounted on a vibration isolation platform. This platform will provide vibration isolation during nominal operations. This platform will be secured to the bottom of the 12PU drawer for launch, using 4 Allen bolts. See figure 8.2.5-1. Prior to the first usage on orbit, these 4 bolts will be removed by pulling the 12PU drawer partially out of the rack and loosening the bolts from underneath the drawer. The 6 launch bolts used to attach the centrifuge to the rack must be removed and replaced during this operation.

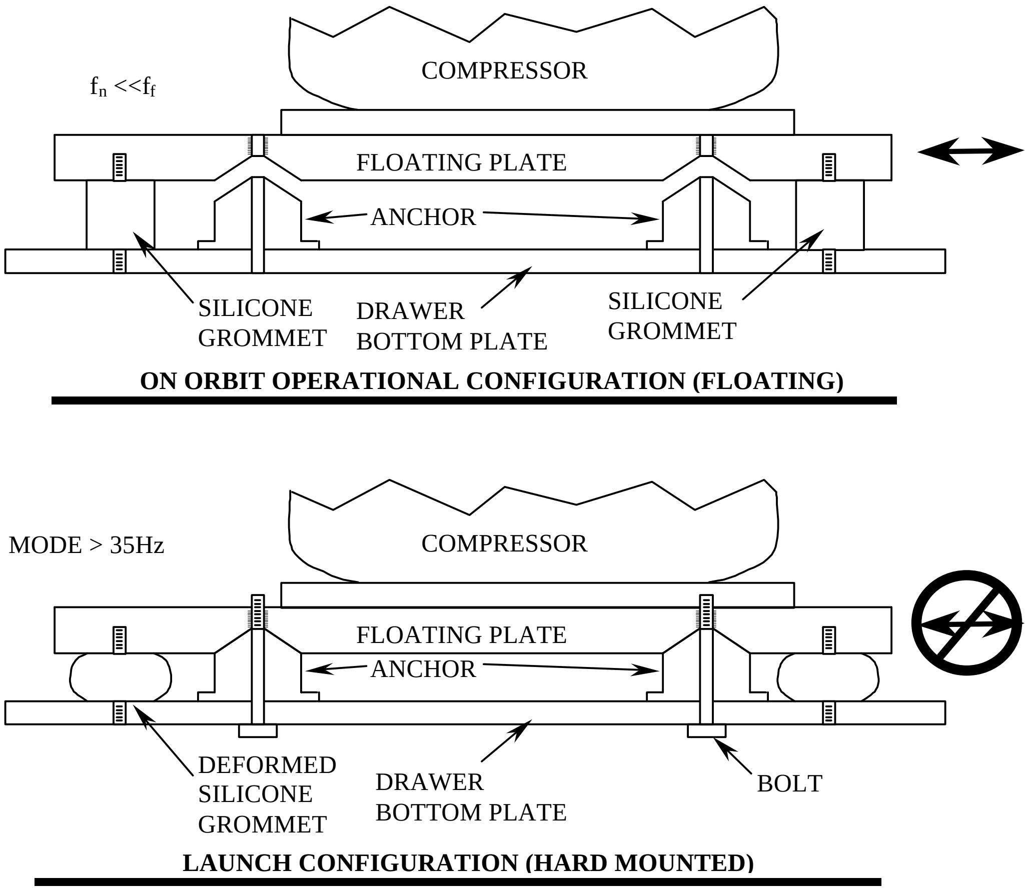


Figure 8.2.5-1

The centrifuge chamber will be wiped down after each spin with a Station provided disinfectant wipe. Any spills will be cleaned up in accordance with the experiment protocol. The crew will also need to wipe any condensation that was formed in the chamber with Station provided dry wipes.

The o-ring around the rotor chamber can easily be checked for damage each time a centrifugation procedure is performed, and replaced when necessary. This maintenance task requires no tools. At present, there is no way to calibrate the centrifuge. The drift of the rotor motor may be measured on orbit, but there is no way to correct this drift.

The air inlet vents will be cleaned as required.

Access to some circuit boards would be possible with the removal of the upper stowage drawer. This activity is not planned and no spares are currently being flown. This activity would be evaluated if a failure were to occur.

8.2.6 Aging and disposal

The design of the refrigerated centrifuge is intended to support the 10 year life of the station.

8.3 REFRIGERATED CENTRIFUGE INTERFACE REQUIREMENTS

8.3.1 Power

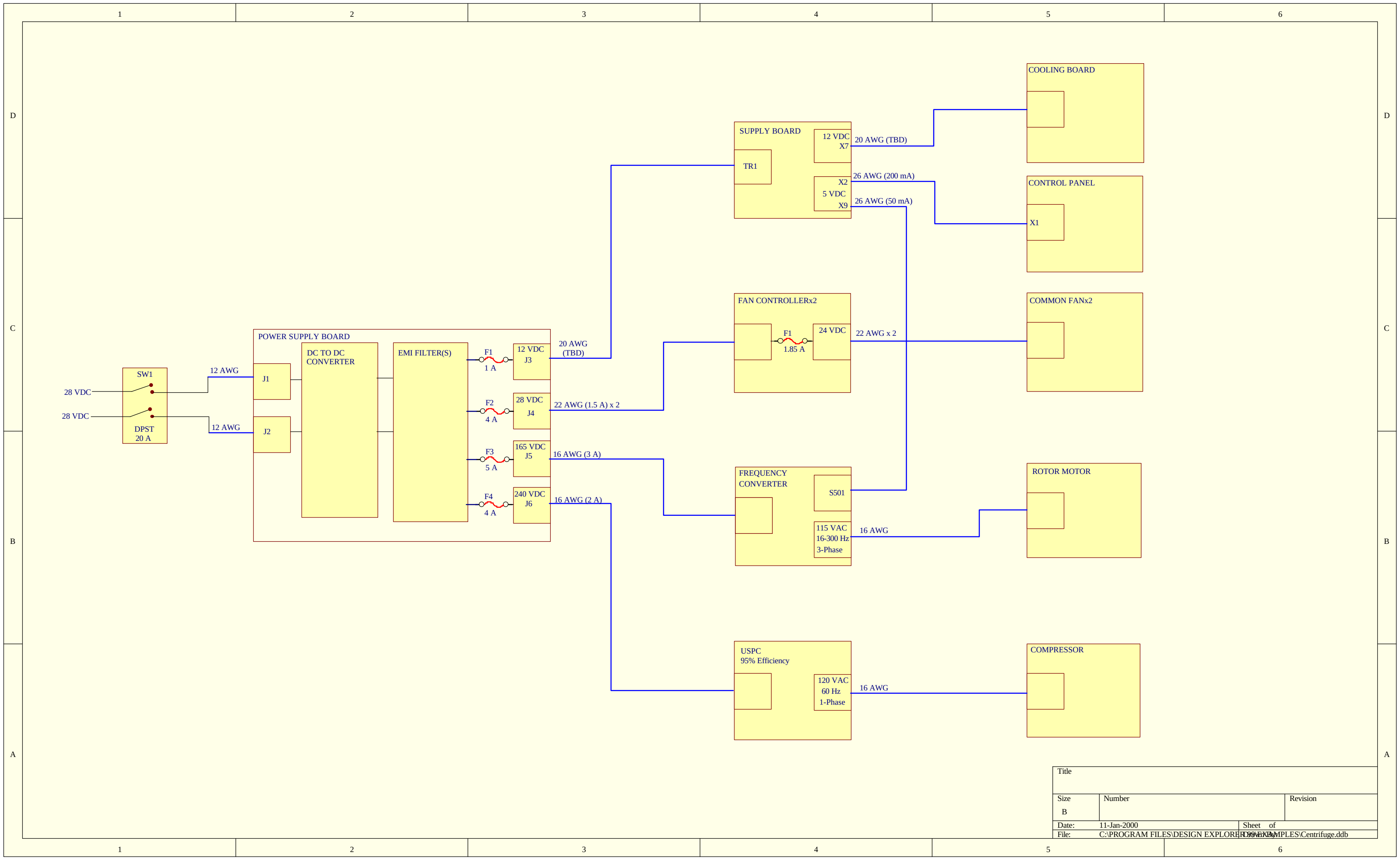
The refrigerated centrifuge will receive electrical power from three 28 VDC rack connector bar interfaces using blind mate connectors. The voltage will be stepped up to 165 VDC internally to power the rotor motor and 240 VDC to power the compressor. See figure 8.3.1-1 for power distribution.

8.3.2 Data

The centrifuge will transmit health and status data through the data connector on the back panel to the Workstation II.

8.4 REFRIGERATED CENTRIFUGE SAFETY ASSESSMENT

ISS/NSTS payload safety critical subsystems are normally subdivided into, pressure systems, radiation, mechanical, structural, electrical, human factors, and materials categories for consideration. The following categories are applicable to the refrigerated centrifuge and are documented on the Form 1230 in Appendix 8A. Unique hazard reports for structural failure (RC-1), high voltages (RC-2), rotating equipment (RC-3), leakage/rupture of a pressure system (RC-4), and failure of latching mechanism (RC-5) are



COOLING BOARD
SUPPLY BOARD
12 VDC X7
TR1
20 AWG (TBD)
26 AWG (200 mA)
X2
5 VDC
X9
26 AWG (50 mA)
CONTROL PANEL
X1
FAN CONTROLLERx2
F1
1.85 A
24 VDC
22 AWG x 2
COMMON FANx2
POWER SUPPLY BOARD
SW1
28 VDC
28 VDC
DPST
20 A
12 AWG
12 AWG
J1
J2
DC TO DC CONVERTER
EMI FILTER(S)
F1
1 A
12 VDC
J3
20 AWG (TBD)
F2
4 A
28 VDC
J4
22 AWG (1.5 A) x 2
F3
5 A
165 VDC
J5
16 AWG (3 A)
F4
4 A
240 VDC
J6
16 AWG (2 A)
FREQUENCY CONVERTER
S501
115 VAC
16-300 Hz
3-Phase
16 AWG
ROTOR MOTOR
USPC
95% Efficiency
120 VAC
60 Hz
1-Phase
16 AWG
COMPRESSOR
Title
Size
B
Number
Revision
Date: 11-Jan-2000
Sheet of
File: C:\PROGRAM FILES\DESIGN EXPLORER 99\EXAMPLES\Centrifuge.ddb

Figure 8.3.1-1

located in Appendix 8B. A list of hazard controls requiring crew procedures or crew training can be found in Appendix 1D at the front of this document.

8.4.1 Human Factors

Construction of the refrigerated centrifuge will meet the requirements specified in SSP 57000, section 3.12.9.2, for sharp edges, corners, or protrusions. No potential pinch points have been identified.

The refrigerated centrifuge meets touch temperature requirements of letter MA2-95-048, “Thermal Limits for Intravehicular Activity (IVA) Touch Temperature”. No experiment protocols are expected to request a temperature less than +4^{o}C since this could cause freezing of the sample, making centrifugation less effective. In the unlikely event a temperature below -18^{o}C is requested, that experiment would be required to provide thermal protection for the crew as necessary.

8.4.2 Materials

All materials selected for the manufacture and construction of flight hardware and equipment, both metallic and non-metallic, meet the requirements specified in applicable requirements documentation (MSFC-HDBK-527/JSC 09604, "Materials Selection List for Space Hardware Systems"; SSP 30233, "Space Station Requirements for Materials and Processes"; NSTS 1700.7B, "Safety Policy and Requirements for Payloads Using the Space Transportation System"; and NSTS 1700.7 ISS Addendum, "Safety Policy and Requirements for Payloads Using the International Space Station"). JSC/EM2 will review and approve all materials for the refrigerated centrifuge and supply the material certification prior to flight.

All LEDs used in the refrigerated centrifuge are plastic. The LCD does not include backlighting and will be covered by a translucent plastic.

8.4.3 Electrical

Circuit protection devices and wire sizes will be selected in accordance with TM102179, " Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electrical Circuits" as interpreted by TA-92-038.

The blind mate electrical connection will be made per procedures with the power to the drawer location and refrigerated centrifuge turned off.

The refrigerated centrifuge will be in compliance with SSP 30237, "Space Station Electromagnetic Emission and Susceptibility Requirements". EMI compatibility testing will be performed.

The centrifuge does have high voltage sources (165VDC and 240VDC) within the power distribution system. These voltages are internal and inaccessible when the drawer is in its powered location within the rack.

No batteries are used in the design of the refrigerated centrifuge.

8.4.4 Rapid Safing

The refrigerated centrifuge will meet the rapid safing requirements of Letter MA2-96-190 and will not impede emergency IVA egress into other pressurized volumes.

8.4.5 Structures

The refrigerated centrifuge will meet the safety critical structure design requirements of NSTS 14046 and SSP 52005 for mission induced loads during all phases of flight. The refrigerated centrifuge will be mounted in the HRF Rack 2 during all mission phases. Six (6) launch bolts, in addition to the 6 slide guides, will be used to attach the centrifuge to the rack for launch.

These bolts will remain in position unless the drawer must be removed from the rack. They will be removed to release the vibration platform, but will be re-inserted after this operation. Structural analysis will verify that positive margins of safety have been achieved. Factors of safety used for structural analysis are 1.25 for yield, 2.0 ultimate. The factors of safety used for fasteners are 1.25 for yield, 2.0 ultimate. Mission load factors are taken from SSSP57000C. The JSC/EM2 materials branch will verify that materials have been selected in accordance with MSFC-SPEC-522B and approve any MUA's. Qualified standard fasteners will be used and properly secured. Fracture control is implemented per the Fracture Control Plan for HRF, LS-71010, in accordance with SSP 52005.

The refrigerated centrifuge contains three fans, two for cooling and one within the condenser. The cooling fans are HRF common fans which is 4.125” in diameter and rotates at 5200 rpm at 28 VDC. The condenser fan is 5.9” in diameter and rotates at 2500rpm. These fans meet the requirements of NASA-STD-5003. The maximum speed of the compressor motor is 3600 rpm.

The refrigerated centrifuge system provides three different rotors. The maximum speed of each rotor is given in the table below.

Rotor Max Capacity	***7-50 ml***	***2-10 ml***	***.4-2.2ml***
Adapters	12 and 7 ml	5 ml	1.5 and .5 ml
Max speed	6000 RPM	5000 RPM	14,000 RPM

The refrigerant, R404a, is under pressure. The high pressure portion of the system is 260psig during operation, while the low pressure portion is 150psig. This is a closed system. The pressure is directly and indirectly monitored via 3 items. A temperature switch in the condenser would turn off the condenser if the temperature reached >60^{o}C. The compressor includes a switch that would turn it off if the current reached >7amps. A pressure sensor is located on high pressure side of the system and will cut power to the compressor at 350 psig. The Maximum Design Pressure of the system is 350 psig based on these controls. The compressor within the system is hermetically sealed and therefore a depress/repress analysis will be performed on this item individually, as well as the drawer as a whole.

8.4.6 Safety Re-verifications

No periodic re-verifications are required to ensure safe operation for the life of this hardware item.

8.4.7 Action Items/Non-compliances/Hardware Anomalies

No action items remain open on this hardware item. Nine agreements were assigned at the Phase I review and have been incorporated into this updated safety package. No non-compliances have been identified with this hardware. No safety-related anomalies have occurred with this hardware item.

Appendix 8A

Standard Hazards
for the Refrigerated Centrifuge

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT		**A. NUMBER** STD- Refrigerated Centrifuge	**B. PHASE** **Phase II**	**C. DATE** Jan 2001
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* HRF – Refrigerated Centrifuge P/N SEG46117400 (w/o stowage)		**HAZARD TITLE** STANDARD HAZARDS	**E. VEHICLE** Shuttle/Station	

F. DESCRIPTION OF HAZARD:	**G. HAZARD CONTROLS:** *(complies with)*	**H. APP.**	**I. VERIFICATION METHOD, REFERENCE AND STATUS:**
1. Structural Failure *(payloads must comply with the listed requirements for all phases of flight)*	a) Designed to meet the standard modular locker stowage requirements of NSTS 21000-IDD-MDK or equivalent IDD___________, or b) Stowed in SPACEHAB per MDC91W5023. *Note: Locker and Soft Stowage items only*	☐ ☐	See unique hazard report RC-1
2. Structural Failure of Sealed or Vented Containers	a) Sealed containers must meet the criteria of NASA-STD-5003, contain a substance which is not a catastrophic hazard if released, be made of conventional metals, and have a maximum delta pressure of 1.5 atm. b) For intentionally vented containers, vents are sized to maintain a 1.4 factor of safety for Shuttle or a 1.5 factor of safety for Station with respect to pressure loads.	☐ ☐	See unique hazard report RC-4 for refrigeration system.
3. Sharp Edges	Meets the intent of one or more of the following: a) NASA-STD-3000 / SSP 50005 b) SLP 2104 c) NSTS 07700 Vol. XIV App. 7 (EVA hardware) d) NSTS 07700 Vol. XIV App. 9 (IVA hardware) / SSP 57000	 ☐ ☐ ☐ ☒	Sharp Edge inspection of as-built hardware. TPS# TBD. OPEN

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT		**A. NUMBER** STD- Refrigerated Centrifuge	**B. PHASE** **Phase II**	**C. DATE** Jan 2001
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* HRF – Refrigerated Centrifuge P/N SEG46117400 (w/o stowage)		**HAZARD TITLE** STANDARD HAZARDS	**E. VEHICLE** Shuttle/Station	

F. DESCRIPTION OF HAZARD:	**G. HAZARD CONTROLS:** *(complies with)*	**H. APP.**	**I. VERIFICATION METHOD, REFERENCE AND STATUS:**
4. Shatterable Material Release	a) All materials are contained.	☒	QA inspection/certification that the LCD is protected by a plastic covering. TPS# TBD. OPEN
	b) Optical glass (i.e. lenses, filters, etc.) components of crew cabin experiment hardware that are non-stressed (no delta pressure) and have passed both a vibration test at flight levels and a post-test visual inspection.	☐	
	c) Payload bay hardware shatterable material components that weigh less than 0.25 lb and are non-stressed (no delta pressure) or non-structural.	☐	
5. Flammable Materials	a) A-rated materials selected from MAPTIS, or	☒	Review/approval of material list by JSC/EM2 Material Branch. Ref. Materials Memo # TBD. OPEN
	b) Flammability assessment per NSTS 22648	☐	
6. Materials Offgassing	a) Offgassing tests of assembled article per NHB 8060.1	☒	Review/approval of offgas testing by JSC/EM2 Materials Branch. Ref. Materials Memo # TBD. OPEN
7. Nonionizing Radiation 7.1 Non-transmitters	a) Pass NSTS 21288 / SSP 30237 EMI compatibility testing, or	☒	Review of test results for successful completion of EMI compatibility testing. Reference TPS# TBD. OPEN
	b) NSTS/MS2 approved analysis	☐	
7.2 Lasers	a) Beams are totally contained at the maximum possible power and there is no crew access, or	☐	N/A
	b) Meet ANSI Z136.1-1993 for class 1, 2, or 3a Lasers (as measured at the source).	☐	

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT		A. NUMBER STD- Refrigerated Centrifuge		B. PHASE **Phase II**	C. DATE Jan 2001
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* HRF – Refrigerated Centrifuge P/N SEG46117400 (w/o stowage)		**HAZARD TITLE** STANDARD HAZARDS		**E. VEHICLE** Shuttle/Station	
F. DESCRIPTION OF HAZARD:	**G. HAZARD CONTROLS:** *(complies with)*	**H. APP.**	**I. VERIFICATION METHOD, REFERENCE AND STATUS:**		
8. Battery Failure *(use of this form is limited to small commercial batteries as listed below)* 8.1 Alkaline-MnO_2, Carbon- Zn, or Zn-Air in sizes D or smaller having 6 or fewer cells either all in parallel or all in series (series/parallel combinations require a unique hazard report), no potential charging source, and cells are in a vented compartment. 8.2 Li-CFx, Li-Iodine, Li-MnO_2, Ni-Cd, Ni-MH, or Ag-Zn which have a capacity of 200 mAh or less, and no more than 2 cells per common circuit.	Pass acceptance tests which include open circuit & loaded voltage measurements, visual examination, and leakage check under vacuum (e.g. 6 hours at 0.1 psia). *Note: Above acceptance testing for button cells in Section 8.2 which are soldered to a circuit board in commercial equipment (not applicable to those button cells in a spring-loaded clip) is limited to a functional check of the equipment utilizing the subject battery.*	☐	N/A *Note: Application and schematic reviewed and approved by JSC/EP5.*		
9. Touch Temperature	a) Meets IVA touch temperature criteria of letter, MA2-95-048. b) Meets EVA touch temperature criteria of NSTS 07700 Vol. XIV App. 7.	☒ ☐	Test/analysis to ensure surfaces do not exceed 49°C or less than -18°C, including a fan failure condition. Reference TPS # TBD. OPEN A warning label for the -20degC possibility will be added. OPEN Note: The centrifuge is capable of reaching a low temperature of -20degC, but this is not expected and would be through an experiment protocol. If a protocol does request this temperature, gloves would be provided as part of the experiment hardware and procedures would be verified through that experiment safety analysis. Addition of warning label for -20degC condition. OPEN		

FLIGHT PAYLOAD STANDARDIZED HAZARD CONTROL REPORT		A. NUMBER STD- Refrigerated Centrifuge	B. PHASE **Phase II**	C. DATE Jan 2001
D. PAYLOAD, DTO, DSO or RME *(Include Part Number(s), if applicable)* HRF – Refrigerated Centrifuge P/N SEG46117400 (w/o stowage)		**HAZARD TITLE** STANDARD HAZARDS	**E. VEHICLE** Shuttle/Station	

F. DESCRIPTION OF HAZARD:	**G. HAZARD CONTROLS:** *(complies with)*	**H. APP.**	**I. VERIFICATION METHOD, REFERENCE AND STATUS:**
10. Electrical Power Distribution	a) Shuttle payload - Meets all circuit protection requirements of Letter TA-92-038. b) Station payload - Meets station interface circuit protection requirements of SSP 57000 and payload circuit protection requirements of Letter TA-92-038.	☐ ☒	Payload requires power from the HRF rack. Review of design to assure implementation of proper wire sizing and circuit protection. QA inspection/certification of as-built hardware to approved drawings and parts lists. Ref. TPS # TBD. OPEN
11. Ignition of Flammable Atmospheres in Payload Bay	All ignition sources are controlled as required in Letter NS2/81-MO82, and MLI grounded per ICD 2-19001.	☐	N/A
12. Rotating Equipment	Rotating equipment meets criteria of NASA-STD-5003 for obvious containment.	☒	Two 4.125" diameter cooling fans will be shrouded and run at 5200 rpm using 28 VDC. See attached data sheet. The condenser fan is 5.9" in diameter and rotates at 2500rpm. QA certification of as-built hardware to approved drawings and parts lists. See unique hazard report RC-3 for rotors. OPEN
13. Mating/demating power connectors	Meets all requirements of Letter MA2-97-093.	☒	Review of crew procedures to show mate/demate of the centrifuge drawer occurs only when the power to the drawer position and unit are off. OPEN
14. Contingency Return and Rapid Safing	a) Shuttle payload - Meets all rapid safing requirements of Letter MA2-96-190. b) Station payload - Meets rapid safing requirements of Letter MA2-96-190, and design shall not impede emergency IVA egress to the remaining adjacent pressurized volumes.	☐ ☒	The centrifuge does not attach to the crew and will not impede emergency IVA egress. CLOSED

APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

Appendix 8B

Unique Hazards for the Refrigerated Centrifuge

PAYLOAD HAZARD REPORT

NO: RC-1

PAYLOAD: HRF – Refrigerated Centrifuge

PHASE: II

SUBSYSTEM: Structures/Mechanisms	**HAZARD GROUP: Collision**	**DATE: Jan 2001**

HAZARD TITLE: Structural Failure

APPLICABLE SAFETY REQUIREMENTS:
NSTS 1700.7B, paragraph 208.1, 208.3
ISS Addendum to NSTS 1700.7B, 208.1, 208.3
NSTS 18798, letter MA2-96-174

X **CATASTROPHIC**
☐ **CRITICAL**

DESCRIPTION OF HAZARD: Structural failure of payload structural elements or attachment hardware results in unrestrained objects in the Orbiter or Space Station module which could impact and injure the crew or impact the orbiter, Space Station, or other payloads.

HAZARD CAUSES:
1. Structural elements of payload equipment lack structural strength to withstand launch, landing, and emergency landing loads, and on-orbit environments (including depressurization, repressurization and imbalance).
2. The use of structural materials which are susceptible to stress corrosion cracking.
*See continuation sheet

HAZARD CONTROLS:
1.1 Safety-critical structure design will be based on worst-case mission induced loads with no negative margins of safety. All designs and tests will be in accordance with NSTS 14046 and SSP 52005. Factors of safety used for structural analysis are 1.25 for yield, 2.0 ultimate. The factors of safety used for fasteners are 1.25 for yield, 2.0 ultimate.
2.1 Materials selected are in accordance with MSFC-SPEC-522B, table 1.
*See continuation sheet.

SAFETY VERIFICATION METHODS:
1.1.1 Structural analysis (Document # LMSEAT-33513) to verify positive margins of safety.
1.1.2 Frequency identification (sine sweep) to be performed per SSP52005.
1.1.3 Qualification and acceptance vibration testing will be performed per SSP52005.
2.1.1 The JSC materials branch, EM2, will review and approve materials.
*See continuation Sheet

STATUS OF VERIFICATION:
1.1.1 OPEN, expected closure 8/15/01.
1.1.2 OPEN, expected closure 8/15/01.
1.1.3 OPEN, expected closure 8/15/01.
2.1.1 OPEN, expected closure 8/15/01.
*See Continuation Sheet

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO: RC-1
PAYLOAD: HRF – Refrigerated Centrifuge	PHASE: II

HAZARD CAUSES (continued):

3. Failure resulting from defective materials or fabrication.
4. Failure resulting from pre-existing flaws.
5. Failure resulting from the use of counterfeit fasteners.
6. Backoff of fasteners causing a release of mass.
7. Improper configuration for return – installation of allen bolts on vibration isolation platform.

HAZARD CONTROLS (continued):

3.1 Safety-critical structures are built in accordance with approved design drawings and parts lists.
3.2 Qualification and acceptance vibration testing will be performed per SSP52005.
4.1 Fracture Control is implemented per the Fracture Control Plan for HRF, LS-71010, in accordance with SSP 52005.
5.1 All structural fasteners will be in conformance with JSC 23642.
6.1 Locktite, self locking nuts and self locking nut plates will be used to preclude the backoff of fasteners.
7.1 Crew procedures will require installation of allen bolts prior to return.

SAFETY VERIFICATION METHODS (continued):

3.1.1 QA certification that structures are built per approved drawings and parts lists.
3.2.1 QA certification that qualification and acceptance vibration testing is performed per SSP52005. TPS # TBD.
4.1.1 Submit fracture control summary report to JSC/EM2
4.1.2 JSC/EM2 review and approval of Fracture Control Summary Report.
5.1.1 Review of design to verify compliance to JSC 23642B.
6.1.1 QA inspection/certification of proper backoff protection.
7.1.1 Review of crew procedures to show installation of allen bolts prior to return.

STATUS OF VERIFICATION:

3.1.1 OPEN, expected closure 8/15/01.
3.2.1 OPEN, expected closure 8/15/01.
4.1.1 OPEN, expected closure 8/15/01.
4.1.2 OPEN, expected closure 8/15/01.
5.1.1 OPEN, expected closure 8/15/01.
6.1.1 OPEN, expected closure 8/15/01.
7.1.1 OPEN, expected closure 12/15/01.

PAYLOAD HAZARD REPORT		NO: RC-2
PAYLOAD: HRF – Refrigerated Centrifuge		**PHASE: II**
SUBSYSTEM: **Electrical**	**HAZARD GROUP:** **Injury/Illness**	**DATE: Jan 2001**

HAZARD TITLE: Electrical Shock

APPLICABLE SAFETY REQUIREMENTS:
NSTS 1700.7B, paragraph 200.1b, 213
ISS Addendum to 1700.7B, paragraph 200.1b, 213

X **CATASTROPHIC**
☐ **CRITICAL**

DESCRIPTION OF HAZARD: Incidental contact by the crew with high voltages can lead to severe burns and possibly other physiological effects. Electrical shock to the flight crew could result from contact with high voltages of 240VDC and 165 VAC within the centrifuge.

HAZARD CAUSES:
1. Defective component, wire, insulation, design and/or workmanship coupled with inadequate bonding/grounding results in shock potential.
2. Incidental contact by the crew with exposed terminals, connectors, energized conductive surfaces.

HAZARD CONTROLS:
1.1 Hardware will be built per approved drawings to preclude the use of damaged components.
1.2 Bonding/grounding accomplished in accordance with SSP30245 (bonding requirements) & SSP30240 (grounding requirements).
2.1 All electronics are enclosed and inaccessible to the crew by design. All external connectors are <32 VDC.

SAFETY VERIFICATION METHODS:
1.1.1 Vendor inspection/certification of as-built hardware to approved drawings and parts lists.
1.2.1 Test of bonding/grounding per SSP30245 & SSP30240, class H for electrically energized equipment.
2.1.1 Review of design to show electronics are enclosed and external connectors are <32VDC.
2.1.2 Vendor inspection/certification of as-built hardware to approved drawings and parts lists.

STATUS OF VERIFICATION:
1.1.1 OPEN, expected closure 8/15/01.
1.2.1 OPEN, expected closure 8/15/01.
2.1.1 OPEN, expected closure 8/15/01.
2.1.2 OPEN, expected closure 8/15/01.

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		

<table>
<tr><td colspan="2">PAYLOAD HAZARD REPORT</td><td>NO: RC-3</td></tr>
<tr><td colspan="2">PAYLOAD: HRF – Refrigerated Centrifuge</td><td>PHASE: II</td></tr>
<tr><td>SUBSYSTEM: Structures, Mechanical</td><td>HAZARD GROUP: Collision</td><td>DATE: Jan 2001</td></tr>
<tr><td colspan="3">HAZARD TITLE: Failure of Rotating Equipment</td></tr>
<tr><td colspan="2">APPLICABLE SAFETY REQUIREMENTS:
NSTS 1700.7B, paragraph 200.2, 200.3, 201.3, 208
ISS Addendum to 1700.7B, paragraph 200.2, 200.3, 201.3, 208</td><td>X CATASTROPHIC
☐ CRITICAL</td></tr>
<tr><td colspan="3">DESCRIPTION OF HAZARD: The breaking up of centrifuge rotor generates debris. This debris can puncture critical components leading to damage to the station or loss of crew.</td></tr>
<tr><td colspan="3">HAZARD CAUSES:
1. Mechanical component failure at high rotation rate due to: inadequate strength, usage of materials susceptible to stress corrosion cracking, initiation and/or propagation of flaws or crack-like defects, or overspeed of rotating equipment due to controller failure. Rotor attachment is via a conical friction fit and restraining nut.
2. Release of mass due to failure of latch mechanism.</td></tr>
<tr><td colspan="3">HAZARD CONTROLS:
1.1 Safety-critical structure design will be based on worst-case mission induced loads with no negative margins of safety. All designs and tests will be in accordance with NSTS 14046 and SSP 52005. Factors of safety used for structural analysis are 1.25 for yield, 2.0 ultimate. The factors of safety used for fasteners are 2.0 ultimate, 1.25 for yield.
1.2 Materials selected are in accordance with MSFC-SPEC-522B, table 1.
1.3 Fracture Control is implemented per the Fracture Control Plan for HRF, LS-71010, in accordance with SSP 52005.
1.4 Mass of rotor would be contained at maximum speed.
See continuation sheet.</td></tr>
<tr><td colspan="3">SAFETY VERIFICATION METHODS:
1.1.1 Structural analysis (Document # LMSEAT33513) to verify positive margins of safety.
1.2.1 The JSC materials branch, EM2, will review and approve materials.
1.3.1 JSC/EM2 review and approval of Fracture Control Summary Report.
1.4.1 Containment analysis (Document # TBD) to verify mass would be contained at maximum.
See continuation sheet.</td></tr>
<tr><td colspan="3">STATUS OF VERIFICATION:
1.1.1 OPEN, expected closure 8/15/01.
1.2.1 OPEN, expected closure 8/15/01.
1.3.1 OPEN, expected closure 8/15/01.
1.4.1 OPEN, expected closure 8/15/01.
see continuation sheet.</td></tr>
</table>

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO: RC-3
PAYLOAD: HRF – Refrigerated Centrifuge	PHASE: II

HAZARD CAUSES (continued):
2. Release of mass due to failure of latch mechanism.

HAZARD CONTROLS (continued):
2.1 The latch consists of an over-center hook with a tab/solenoid to hold it in place. An optical switch with LED indicator will provide a visual indication that the tab is in the locked position.
2.2 The release handle includes a secondary mechanical lock to preclude a crew kick load from unlatching the door in the event the tab mechanism fails.
2.3 In the event of failure of the tab lock and inadvertent door opening, a hard-wired switch would sense the hook opening and cause a braking of the rotor. The rotor would stop within 30 seconds.

SAFETY VERIFICATION METHODS (continued):
2.1.1 Review of design to show over-center hook with tab lock.
2.1.2 Functional test of tab lock and LED indicator.
2.2.1 Review of design to show secondary mechanical lock on door handle.
2.3.1 Test to show rotor would stop within 30 seconds if the door is opened during operation.

STATUS OF VERIFICATION:
2.1.1 OPEN, expected closure 8/15/01.
2.1.2 OPEN, expected closure 8/15/01.
2.2.1 OPEN, expected closure 8/15/01.
2.3.1 OPEN, expected closure 8/15/01.

PAYLOAD HAZARD REPORT

NO: RC-4

PAYLOAD: **HRF – Refrigerated Centrifuge**

PHASE: **II**

SUBSYSTEM: Pressure System	HAZARD GROUP: Injury/Illness	DATE: Jan 2001

HAZARD TITLE: Rupture of Pressure System

APPLICABLE SAFETY REQUIREMENTS:
NSTS 1700.7B, 208.4
ISS Addendum to NSTS 1700.7B, 208.4

X **CATASTROPHIC**

CRITICAL

DESCRIPTION OF HAZARD:
Failure of the pressure containment system or any lines could result in exposure of the crew and equipment to high pressure and shrapnel. The system has a maximum pressure of 350 psi. Leakage of freon (R404a) gas into the habitable area from the centrifuge refrigeration system is not considered a hazard because R404a is a toxicity level 0 (Ref memo #458) and does not have a deleterious effect on the ECLSS system (ref attached email). Note: 250g of freon will be used within the system.

HAZARD CAUSES:
1. Inadequate design strength to withstand MDP, and other loading environments.
See continuation sheet

HAZARD CONTROLS:
1.1 Lines and fitting will have a FOS of ≥4 times MDP. Components have been designed using a FOS ≥2.5 times MDP. MDP of high pressure side is 350 psi. See attached pressure matrix and schematic. Note: MDP is 150 psig for low pressure side. MDP is based on nominal operation with proper controls.
See continuation sheet.

SAFETY VERIFICATION METHODS:
1.1.1 Pressure matrix of all lines, fittings, and components showing FOS is attached.
1.1.2 QA verification that as-built hardware in accordance with specified part numbers.
1.1.3 System leak integrity test will be performed on the flight unit.
1.1.4 Vibration testing will be performed per SSP 52005.
See continuation Sheet

STATUS OF VERIFICATION:
1.1.1 CLOSED.
1.1.2 OPEN, expected closure 8/15/01.
1.1.3 OPEN, expected closure 8/15/01.
1.1.4 OPEN, expected closure 8/15/01.
See Continuation Sheet

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO: RC-4
PAYLOAD: HRF – REFRIGERATED CENTRIFUGE	PHASE: II

HAZARD CAUSES (continued):

2. Improper material selection and processing, including usage of stress corrosion sensitive materials.
3. Improper filling of system.
4. Materials incompatibility.
5. Propagation of crack-like defects.
6. Improper workmanship and/or assembly.

HAZARD CONTROLS (continued):

2.1 Materials are selected per MSFC-HDBK-527/ JSC-09604 and MSPC-SPEC 522B for stress corrosion resistance.
3.1 System will be filled with ≤ 250g of freon R404a.
3.2 System will be filled using only R404a.
4.1 Materials chosen will be compatible with R404a.
4.2 Cleaning fluids will be compatible with the system.
5.1 Fracture Control is implemented per the Fracture Control Plan for HRF, LS-71010, in accordance with SSP 52005.
6.1 Hardware will be built in accordance with approved design drawings and assembled as per approved procedures.

SAFETY VERIFICATION METHODS (continued):

2.1.1 JSC/EM2 approval of all materials and their application, Materials Cert. # TBD.
3.1.1 QA verification that system is filled with ≤250g.
3.2.1 Vendor Certificated of Compliance showing R404a.
3.2.2 QA certification that system was filled using R404a.
4.1.1 Vendor provided compatibility data.
4.2.1 Vendor provided compatibility data.
5.1.1 Submit fracture control summary report to JSC/EM2
5.1.2 JSC/EM2 review and approval of fracture control summary report.
6.1.1 QA certification of as-built hardware to approved drawings and parts lists.

STATUS OF VERIFICATION:

2.1.1 OPEN, expected closure 8/15/01.
3.1.1 OPEN, expected closure 8/15/01.
3.2.1 OPEN, expected closure 8/15/01.
3.2.2 OPEN, expected closure 8/15/01.
4.1.1 OPEN, expected closure 8/15/01.
4.2.1 OPEN, expected closure 8/15/01.
5.1.1 OPEN, expected closure 8/15/01.
5.1.2 OPEN, expected closure 8/15/01.
6.1.1 OPEN, expected closure 8/15/01.

TOXICOLOGY GROUP
BIOMEDICAL OPERATIONS BRANCH
NASA JOHNSON SPACE CENTER, SD2
HOUSTON, TX 77058

MEMO _458_
PHONE: 281-483-7187
FAX: 281-483-3058

To: Sharon Brandt/LM/S361

FROM: Martin E. Coleman, Ph.D./SD2
Toxicologist

DATE: Feb 17, 1999

SUBJECT: Toxicological Acceptability of Freon 404A in Refrigerated Centrifuge (RC)

MESSAGE

You requested a toxicological hazard assessment of the Freon 404A (DuPont SUVA HP62) to be used in the International Space Station (ISS) refrigerated centrifuge (RC). The RC will be transported to the ISS during ISS-UF-1 (STS-104) or a subsequent flight. In many instances, biological samples taken from the RC will be then be placed in the Minus Eighty Degree Laboratory Freezer for the ISS (MELFI). Some background data on this Freon are given below:

Chemical Names, Formulas and Percentages: Pentafluoroethane (HFC-125) (CF_3CHF_2) (44% v/v)
(of the three components) 1,1,1-Trifluoroethane (HFC-143A) (CF_3CH_3) (52%)
1,1,1,2-Tetrafluoroethane (HFC-134A) (CF_3CH_2F)(4%)
Amount Used in RC:170 g
Projected ISS (566 m^3 volume) Average Concentration in the Event of Escape: 140 ppm (345 mg/m^3)
Toxic Hazard Level: 0 (nonhazard)

This projected ISS volume of 474 m^3 was based on the assumption that the Freon 404A would dissipate into the ISS volumes which have a common airflow, the U.S. Lab (100 m^3), the Japanese Experiment Module (125 m^3), the 2 Docking and Stowage Modules (48 m^3 each), the European Space Agency Columbus Module (77 m^3), the three Experiment Modules (48 m^3 each) and the ISS Life Support Module (48 m^3). It did not include the Russian modules, since they have their own airflow system.

Note in the above table that the 170 g of Freon 404B is listed as a nonhazard. This is because an extensive review of the toxicology literature revealed a low level of toxicity for all three components. As an example, some toxicity data on one of these compounds, pentafluoroethane, is summarized below:

4-Hour Inhalation LC50 in rats: >800,000 ppm (>80%)
Inhalation Exposure in Rats For 4-13 Weeks: No effect at 50,000 ppm (5%)
Cardiac Arrhythmias in Dogs After I. V. Injection of Epinephrine: None at 75,000 ppm
Embryotoxicity and Teratogenicity Studies in Rats: No effect at 50,000 ppm
Metabolism (Breakdown in the Body): Negligible
Literature Reference to Toxicity Data: T. Kawano, et.al., Fund. & Appld. Toxicol. 28:223-31, 1985

Note: There were many other published reports in the toxicology literature for this and the two other compounds, all with similar results.

Manufacturer's Recommended Workplace Exposure Limit: 1,000 ppm, 4,910 mg/m^3.

Extra Information: Effects on Stratospheric Ozone: none

Note that the projected ISS concentration of Freon 404A would be only a fraction (about 1/7) the manufacturer's recommended limit for years of workplace exposure to one of the prototype components, which reinforces my assessment of this Freon mix as being a nonhazard. I hope that this level 0 toxic hazard assessment will be useful in the design of the RC safety features.

Original signed by: Martin E. Coleman, Ph.D.
Toxicologist
Freons/Freon 404B.DOC

C.C.
PSRP Executive Secretary/NC4
Dan Londa/SAIC/NC44
Eric Harvey/SAIC/NC44
Charles Winter/SAIC/NC44
Skip Larsen/MA2
Dave O'Brien/MA2
Robert Alexander/NE
Sharon Brandt/LM/S361
Howard Nguyen/EA5
Diana Garcia/LM4/SO6
Bill Koelle/MDA-HSV
Tim Allen/TBE-HSV
Mike Barratt/SD2
John James/SD2
Roger Billica/SD2
Hector Garcia/Wyle/SD2
ISS File
Desk File
Refrigerator File
Freon File

PAYLOAD HAZARD REPORT		**NO:** RC-5
PAYLOAD: HRF – Refrigerated Centrifuge		**PHASE: II**
SUBSYSTEM: Structural, Mechanical	**HAZARD GROUP:** Injury/Illness	**DATE: Jan 2001**

HAZARD TITLE: Failure of latching mechanism

APPLICABLE SAFETY REQUIREMENTS:
NSTS 1700.7B, paragraph 220.2c
ISS Addendum to 1700.7B, paragraph 220.2c

X **CATASTROPHIC**
☐ **CRITICAL**

DESCRIPTION OF HAZARD: The latch mechanism on the centrifuge door fails exposing the rotor causing injury/illness to the crew.

HAZARD CAUSES:
1. Failure of the latching mechanism on the centrifuge door and the crew inadvertently contacting the rotating rotor.

HAZARD CONTROLS:
1.1 The latch consists of an over-center pawl with a tab/solenoid to hold it in place. An optical switch with LED indicator will provide a visual indication that the tab is in the locked position.
1.2 The latch includes a hard-wired switch which would send a command to brake the rotor should the pawl be unhooked. Once the brake is applied, the rotor stops spinning within 30 seconds.
1.3 The crew will be instructed to look inside the centrifuge using the lexan window to ensure all spinning has stopped prior to opening the door.
Note: The front panel of the centrifuge includes an LED which is illuminated any time the rotor is spinning and the RPM value is displayed on the LCD.

SAFETY VERIFICATION METHODS:
1.1.1 Review of design to show over-center hook with tab lock.
1.1.2 Functional test of tab lock and LED indicator.
1.2.1 Test to show switch would be activated causing the brake to be applied to the rotor.
1.2.2 Test to show rotor would stop within 30 seconds once the brake is applied, using max RPM (worst case).
1.3.1 Review of crew procedures to show that crew is instructed to check window prior to opening centrifuge.

STATUS OF VERIFICATION:
1.1.1 OPEN, expected closure 8/15/01.
1.1.2 OPEN, expected closure 8/15/01.
1.2.1 OPEN, expected closure 8/15/01.
1.2.2 OPEN, expected closure 8/15/01.
1.3.1 OPEN, expected closure 8/15/01.

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		